Atmospheric transparency in the optical and near IR range above the Shatdzhatmaz summit

Olga Voziakova[a]

[a]Sternberg Astronomical Institute, Universitetsky prosp., 13, Moscow, Russia

ABSTRACT

The study of atmospheric extinction based on the MASS data has been carried out using the classical photometric pairs method. The extinction in V band can be estimated at $0.^m19$. The water vapour content has been derived from GPS measurements. The median value of PWV for clear nights is equal to 7.7 mm.

Keywords: site testing, extinction, MASS, PWV, GPS

1. ATMOSPHERIC EXTINCTION IN THE MASS SPECTRAL BAND

MASS-DIMM instrument has been working on Shatdzhatmaz summit for over three years. Being developed for scintillation measurements, MASS is a proper photoelectric photometer. We use star fluxes measured by MASS in the greater apertures C and D for the atmospheric extinction investigation.[1] We do not apply the Bouguer method because it implies the stability of atmospheric extinction during the night. Unfortunately, such conditions generally do not take place, particularly in the Caucasus. To allow for extinction variations we employ a method based on photometric pairs. Unlike the classical one, we use instrumental magnitudes of extinction stars. It was necessary, therefore, to make a list of stars with determined instrumental magnitudes m_{mass} in the MASS photometrical band ($\lambda_{eff} = 481$ nm).

Seventeen stars were selected by following criteria: non-variable, approximately A0 spectrum, high culminating in the Caucasus. We observed these stars from August 2008 to October 2010. Each clear night they were measured every 1.5 hours on equal and different air masses. To derive the m_{mass} only best nights with small transparency variations have been selected. The system of 1065 equations with 171 unknowns has been worked out. The unknowns are m_{mass} of 17 standard stars and the effective extinctions of 154 nights. As the zero point of our photometric system we have chosen a star γ Gem of A0IV type with $B - V = 0$. We assign to m_{mass} of this star its m_B value from BS catalogue. The system has been solved by the least squares method. Table 1 lists the derived magnitudes. Their errors average out to $0.^m003$, which introduce an error of about $0.^m01$ into the extinction calculation.

Using magnitudes from Table 1 we obtain the fine extinction variation during the night. In Fig. 1 (left) the distribution of 1040 extinction measurements is presented . The median is $0.^m23$ (1st quartile, $0.^m20$; 3rd quartile, $0.^m27$). The theoretical Rayleigh extinction for Shatdzhatmaz summit (2100 meters above sea level) is $0.^m16$ in the $MASS$ band and $0.^m13$ in V band*. The total extinction in V band can be estimated at $0.^m19$ on the assumption that aerosol is neutral.

In Fig. 1 (right) the seasonal behaviour of the median extinction is shown. One can see that minimum extinction is observed in winter. In the same period there are many clear nights.

E-mail: ovoz@sai.msu.ru

*The atmospheric transparency was modelled using MODTRAN[2] for A0V type.

Table 1. The list of photometric stars

| star	α_{2000}	δ_{2000}	m_{mass}	σ_m	type
β Ari	01 54 38	+20 48 29	2.721	0.003	A5V
β Tri	02 09 33	+34 59 14	3.084	0.003	A5II
η Tau	03 47 29	+24 06 18	2.841	0.003	B7IIIe
β Tau	05 26 18	+28 36 27	1.605	0.002	B7III
γ Gem	06 37 43	+16 23 57	1.930	0.000	A0IV
β UMa	11 01 51	+56 22 57	2.342	0.002	A1V
δ Leo	11 14 07	+20 31 25	2.612	0.003	A4V
β Leo	11 49 04	+14 34 19	2.181	0.005	A3V
γ UMa	11 53 50	+53 41 41	2.423	0.003	A0Ve
ϵ UMa	12 54 02	+55 57 35	1.749	0.002	A0pCr
η UMa	13 47 32	+49 18 48	1.780	0.003	B3V
ζ Dra	17 08 47	+65 42 53	3.116	0.003	B6III
δ Her	17 15 02	+24 50 21	3.158	0.003	A3IV
γ Lyr	18 58 57	+32 41 22	3.221	0.003	B9III
ζ Aql	19 05 25	+13 51 48	2.989	0.004	A0Vn
α Cep	21 18 35	+62 35 08	2.562	0.003	A7V
α Peg	23 04 46	+15 12 19	2.466	0.005	B9Vs
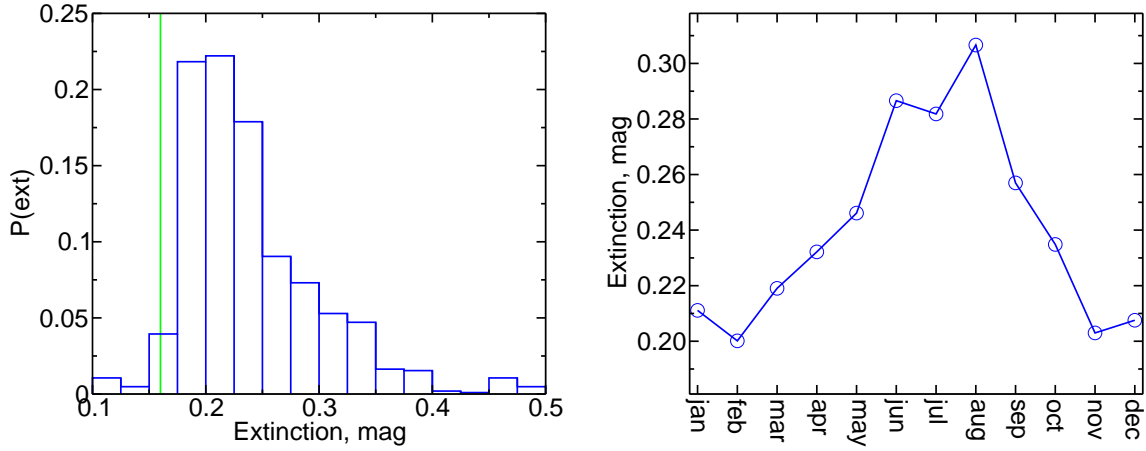
Figure 1. *Left:* Distribution of atmospheric extinction in the $MASS$ band. Vertical green line represents theoretical Rayleigh extinction for Shatdzhatmaz. *Right:* Seasonal behaviour of median atmospheric extiction.

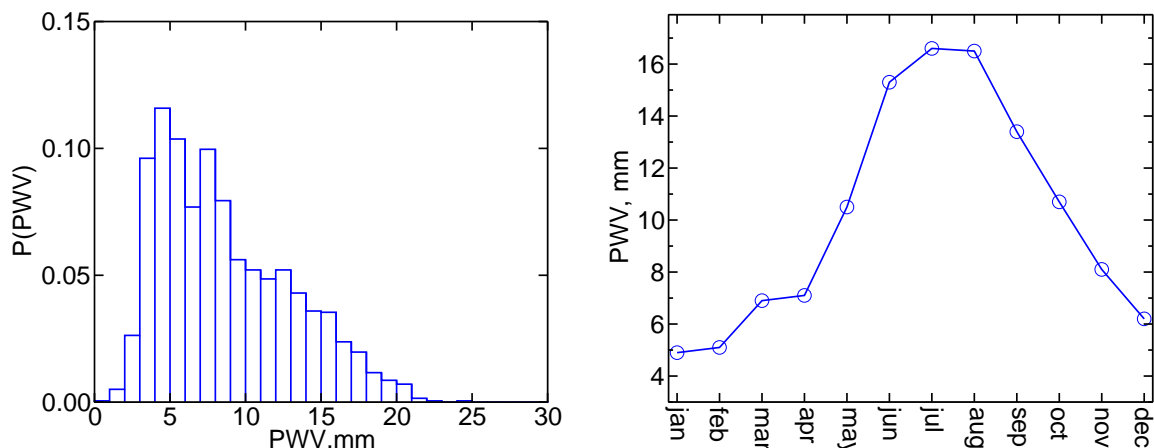Figure 2. *Left:* Distribution of precipitable water vapour on clear nights. *Right:* The seasonal behaviour of precipitable water vapour.

2. ATMOSPHERIC TRANSPARENCY IN THE NEAR IR RANGE

As well known, the transparency of the atmosphere in the IR range is determined by the water vapour content. We estimate the amount of precipitable water using zenith wet delay of GPS signal.[3] Since the Caucasus is a rather wet region, the accuracy of this method is sufficient. The GPS data were obtained from a GPS receiver[†], located on the territory of the Solar Station at a distance of 800 meters from the MASS-DIMM tower. The meteo station is 100 meters away from GPS. The meteo data were kindly provided by the Kislovodsk station of the A.M.Obukhov Institute of Atmospheric Physics (Russian Academy of Sciences).

The median value of PWV estimated on the total GPS data set is equal to 9.1 mm (1st quartile, 6.1 mm; 3rd quartile, 13.9 mm). Distribution of PWV on clear nights is given in Fig. 2 (left). The median of this sample is 7.7 mm (1st quartile, 5.1 mm; 3rd quartile, 11.8 mm). The 7.7 mm corresponds to atmospheric extinction for A0V-star in J band of $0.^m26$, in H and K bands of $0.^m12$. The water vapour content displays an obvious seasonal cycle (Fig. 2, right), most likely due to seasonal course of temperature. It is seen that winter and spring are the best seasons for infrared observations.

3. SOME ATTEMPTS TO PREDICT ATMOSPHERIC CONDITIONS FROM GROUND-BASED METEOROLOGICAL OBSERVATIONS.

It would be useful to find a way to predict the night sky conditions by means of simple weather observations. To clear sky monitoring we use the Boltwood cloud sensor located at the Solar Station. The meteo data are provided by the Kislovodsk station of the A.M.Obukhov Instutute of Atmospheric Physics and our automatic site monitor (ASM).[4]

The relationship between sky temperature and atmospheric extinction in the $MASS$ band is shown in Fig. 3 (left).

We have calculated surface absolute humidity using the dew point temperature and air temperature. Absolute humidity is the density of water vapour $D_w(kg/m^3)$. From the ideal gas law equation:

$$D_w = \frac{P_w}{(T_c + 273.15)R_w},$$

where P_w is water vapour pressure in Pa,
$R_w = 461.5\ (J\,kg^{-1}\,K^{-1})$ is the specific gas constant for water vapour, and

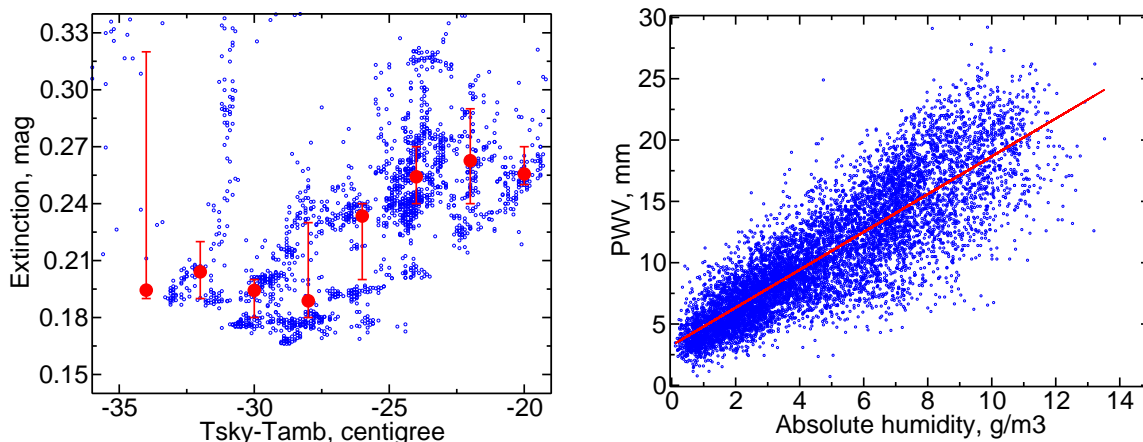[†]The GPS receiver was installed by Sternberg Astronomical Institute in the frame of the geodynamics research.

Figure 3. *Left:* The cloud sensors's sky temperature versus atmospheric extinction in the $MASS$ band. Red line is the median extinction in 2-centigree bins. *Right:* Absolute humidity versus PWV. The linear fit is shown as a red line (see text).

T_c is the temperature in degrees Celsius.

From Magnus-Tetens approximation:[5]

$$P_w = 611 \cdot 10^{\frac{7.5 T_{dc}}{237.7 + T_{dc}}},$$

where T_{dc} is the dew point temperature in degrees Celsius.

Fig. 3 (right) represents surface absolute humidity versus column of precipitable water vapour. This relationship can be fitted by the linear regression: $PWV = 3.2514 + 1.5419 \cdot D_w$, where PWV is measured in mm, D_w is the surface absolute humidity in g/m^3. Rms error is 2.62 mm.

Figurs 3 show a quite wide scatter, which means that we have to look for additional parameters of these relations.

4. CONCLUSIONS

MASS data can be useful not only for atmospheric profiling but also for transparency measuring, e.g., for realtime observation scheduling by photometric stability criterion.

In spite of rather high humidity the observations in the near IR range may be carried out in the Caucasus region.

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